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Developing and Using an Expert System for Planning the Production of Structural Piece-Parts

VIB-2

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ABSTRACT

This paper presents an example of how expert systems can be developed and used for planning structural piece-part production. First, expert systems are briefly and generically described. Then the production processes within a shipyard-like structural piece-part production facility are defined within an expert system "shell"; i.e., the "objects", "attributes", and "rules" describing the production process are established and explained. Then various structural piece-parts are described to the system and the system identifies the required production processes for each described part. The inference process underlying the identification of these processes is described for each of these parts. Finally, potential applications of expert systems to other areas of shipbuilding operations are discussed.

EXPERT SYSTEMS, A GENERAL DESCRIPTION

The intent of this paper is to build on previous presentations on the application of expert systems in a shipbuilding environment (l)(2) by providing an actual example of a potential expert system application to shipbuilding. But first, a general overview of expert systems is in order.

Expert systems have evolved from within the "artificial intelligence" area of computer science. As the name implies, the intent of an expert system is to emulate the decision-making process of an "expert" within a specific domain, or area of interest. In this way, expert systems differ from traditional computer applications as they lend themselves more toward the resolution of problems with uncertainties in supporting data, and/or with large numbers of exceptions and potential options which would make it virtually impossible to derive singular "optimum" solutions. An expert system is "rule driven" meaning that a "good" solution is derived based on rules and an associated decision-making hierarchy which have been provided by an "expert".

Expert system software tools, called "shells," are created in languages such as "C," but have evolved to the point where users need not be familiar with underlying code. Users are only required to be familiar with an overlying, and fairly straightforward information format and English syntax to describe their domains of interest. Note that the author is not a computer scientist, nor had he any user experience with expert systems until October, 1990.

The representation of a particular domain within an expert system is called a knowledgebase. A knowledgebase is made up of objects, object attributes, attribute values rules and m. An object is any group of information which has meaning. An object can have a name like "ship" and can also have attributes such as "length", "draft", etc. Each attribute can in turn have a value, such as "draft=10 m (33ft)."

Rules are developed to describe how the objects within the domain interrelate. These rules are generally in an "if...then...else..." type of format. For example, a rule could be written to determine which drydock a particular ship can use, as follows: If ship draft ≥10 m (33 ft) then drydock number is 2. This example assumes that another object called "drydock" has also been defined.

Goals simply establish which object attributes the system is to solve for. In the example above, the goal would be to solve for the object attribute "drydock number."

Modern expert system shells can automatically generate objects and attributes from rules as these rules are defined in the knowledgebase, or the function of object and attribute definition can be independent of rule definition.

A knowledgebase is developed through "knowledge acquisition" and "knowledge engineering". "Knowledge acquisition" is the process of identifying the objects, attributes, values, and rules that represent a domain, in essence identifying as accurately as possible how the domain of interest really works. This is done by interviewing, video taping, and working with the real experts within the working domain. The process of assimilating this domain information

into a system-usable form, and actually creating the knowledgebase is called "knowledge r engineering".

Expert systems become smarter as the domain is defined with greater accuracy and in more detail within the knowledgebase. For example, the rule that was written earlier for determining which drydock a ship can use becomes smarter with the addition of more domain information: If shin draft≥10 m (33 ft) and ship length≤200 m (656 ft) then drydock number is 2. In this case. another dimensional limitation of the domain has been defined, and the expert system using this rule can infer a smarter solution than it could have using the rule as it was previously written.

AN EXAMPLE SHIPYARD DOMAIN: STRUCTURAL PIECE-PART PRODUCTION

When developing an expert system, it is very important to establish boundaries which limit the scope of knowledgebase development work to a well defined domain. For the purposes of presenting an understandable example within the limitations of this paper, the example presented will be limited to structural piece-part production excluding surface preparation and coating processes, lay-off processes, and assembly processes (the production of "superparts," which are made up of multiple pieces, is not considered in this example). The fabrication facility and processes in this example are intended to be generic and capable of producing approximately fifty-thousand tons of structural piece parts annually when utilized at a high level.

Definition of Production Process Objects, Attributes, and Attribute Values

Following is a list of the structural piece-part production processes that have been defined as objects in the knowledgebase. The layout of the example facility is shown in Figure 1.

Burning Processes:
- Flame Planer 1, FPl
- Flame Planer 2, FP2
- N/C 2-Axis, BRl
- N/C Plasma, BR2

Press Processes:
- Brake Press, PRl
- 1500 Ton Press, PR2
- 37.5 Ton Press, PR3
- 600 Ton Press, PR4
- Frame Bender, PR5
- 250 Ton Press, PR6
- 60 Ton Cold Press, PR7

Roll Processes:
- 2000 Ton Roll, RLl
- 12' Roll, RL2

Planers:
- 40' Edge Planer, PLl

Drills:
- plate Drill. DRl
- Shape Drill, DR2

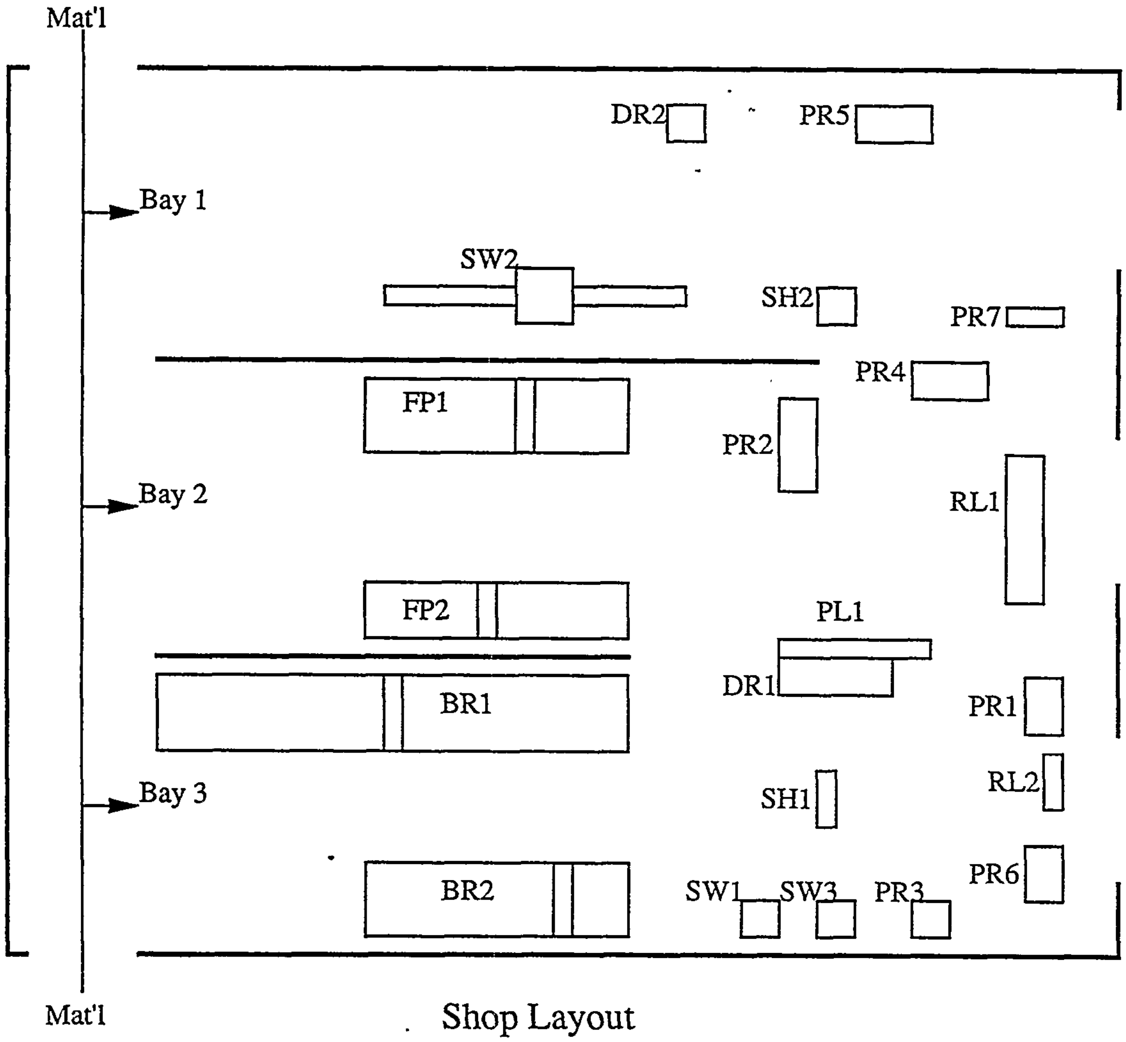
Saws:
- Band Saw, SW1
- Hydraulic Band Saw, SW2
- Contour Band Saw, SW3

Shears:
- Shear, SHl
- 100 Ton Punch, SH2

The generic processes of "cut", "edge prep", and "form" have also been defined within the example knowledgebase. These generic processes and their associated attributes can be inherited by the specific processes listed above based on their capabilities. For instance, the N/C Plasma process can both cut and edge prep. Therefore, this process can inherit the attributes of theses two generic processes, and then values relating specifically to the N/C plasma process can be defined for these attributes. Following is a list of the attributes associated with each generic process. For a detailed list of specific process attribute values which define the capabilities of each specific process, refer to the complete object and attribute listing in Appendix A.

Cut:
- # of axes
- # of master cut tools
- # of slave cut tools
- angle cut maximum
- automation level
- cut accuracy
- cut configuration
- cut length maximum
- cut location
- cut part depth maximum
- cut part length maximum
- cut part width maximum
- cut routing code
- hole diameter maximum
- mat'1 cut thickness maximum

Edge Prep:
- bevel accuracy
- bevel configuration
- bevel degrees maximum
- edge prep length maximum
- edge prep location
- edge prep part depth maximum
- edge prep part length maximum
- edge prep part width maximum
- edge prep routing code
- edge prep thickness maximum



Shop Layout

Figure 1

Form.
- form accuracy
- forming location
- forming part depth maximum
- forming part length maximum
- forming part width maximum
- forming routing code
- outside radius minimum
- roll degrees maximum
- section modulus maximum

Definition of Rules

Following are the rules which have been established as representative of how the many production processes relate to the fabrication of specific parts. These rules are not intended to represent all of the production relationships within this facility. They represent only basic production relationships to help keep this example simple. Also, the detailed and accurate description of any domain is a continuous, evolutionary process. As exceptions to the established rules are identified, existing rules are refined or additional rules are defined to address them. In its present state of development, this knowledgebase might, for example, narrow the cut process possibilities for the fabrication of a specific part to two specific processes from the eleven processes with cut capability. If this occurs, the rules established thus far do not provide enough knowledge to allow the system to decide between the remaining two processes; the rules require further refinement, or additional rules are required to address this particular exception.

Rule :
IF the part shape is rolled or knuckled,
THEN the part process is form process.

Rule :
IF the part edge/end preparation is beveled,
THEN the part process is edge prep process.

Rule 3:
IF the part size is smaller than stock,
THEN the part process is cut process.

Rule 4:
IF the part size is stock, and the part mat'1 area is less than stock mat'1 area (hole cut required),
THEN the part process is cut process.

Rule 5:
IF the part size is larger than stock,
THEN the part process is fabricate superpart (joining process).

Rule 6:
IF the part material is aluminum,
THEN the part thickness aluminum = part material thickness to be cut,
ELSE the part thickness aluminum = 0, and the part section modulus aluminum = 0.

Rule 7:
IF the part material is steel,
THEN the part thickness steel = part material thickness to be cut,
ELSE the part thickness steel = 0, and the part section modulus steel = 0.

Rule 8:
IF the part process is cut process,
and the part length $\leq$ cut process cut part length max, and the part width $\leq$ cut process cut part width max, and the part depth $\leq$ cut process cut part depth max, and the part cut dimensional accuracy requirement $\geq$ cut process cut accuracy, and the part thickness steel $\leq$ cut process material cut thickness steel max, and the part thickness aluminum $\leq$ cut process material cut thickness aluminum max, and the part hole cut diameter $\leq$ cut process hole diameter max, and the part angle max variation from 90 degrees $\leq$ cut process angle cut max, and the part cut configuration is the cut process cut configuration, and the part max cut length $\leq$ cut process cut length max,
THEN the part cut method is Object Name <cut process>, and the part cut routing code is the cut process routing code, and the part cut location is the cut process cut location.

Rule 9:
IF the part process is form process,
and the part length $\leq$ form process form part length max, and the part width $\leq$ form process form part width max, and the part depth $\leq$ form process form part depth max, and the part roll radius accuracy requirement $\geq$ form process form accuracy, and the part section modulus steel $\leq$ form process section modulus steel max, and the part section modulus aluminum $\leq$ form process section modulus aluminum max, and the part outside radius $\geq$ form process outside radius minimum, and the part roll degrees $\leq$ form process roll degrees max, and the part web h/t $\leq$ the form process h/t max,
THEN the part forming method is Object Name <form process>, and the part forming routing code is the form process routing code, and the part forming location is the form process form location.

Rule 10:
IF the part process is edge prep process,
and the part length $\leq$ edge prep process edge prep part length max, and the part width $\leq$ edge prep process edge prep part width max, and the part depth $\leq$ edge prep process edge prep part depth max, and the part max bevel angle required $\leq$ edge prep process bevel degrees max, and the part thickness steel $\leq$ edge prep process material edge prep thickness steel max, and the part thickness aluminum $\leq$ edge prep process material edge prep thickness aluminum max, and the part edge prep configuration is the edge prep process edge prep configuration, and the part max edge prep length $\leq$ edge prep process edge prep length max,
THEN the part edge prep method is Object Name <edge prep process>, and the part edge prep routing code is the edge prep process routing code, and the part edge prep location is the edge prep process edge prep location.

Rule 11:
IF the part type is plate,
THEN the part web h/t=O, and the part material thickness to be cut = part depth.

Rule 12:
IF the part type is shape,
THEN the part web h/t= part depth * 0.94/ part web thickness, and part material thickness to be cut = part flange thickness.

As these rules were created, the "part" object and its associated attributes were created automatically by the expert system shell. No values were specified for the part attributes so that the expert system will prompt the user for these values during the inference process. Also, it is clear that some significant generalizations have been made within the rules for the purpose of simplification. These generalizations will probably require further refinement as the user encounters the specific circumstances where the rules do not provide sensible solutions.

A complete list of these rules in system format is provided in Appendix B.

Definition of Goals

The goals established for this expert system application are to identify the general processes, such as cut, edge prep, and/or form, required to produce a specified structural piece-part, and then to identify the specific shop processes in the defined facility that are required to carry out the general processes in producing the piece-part. In system language, the object attributes that have been identified for solution are:

- part process,
- part cut method,
- part cut routing code,
- part cut location,
- part forming method
- part forming routing code,
- part forming location,
- part edge prep method,
- part edge prep routing code, and
- part edge prep location.

USING THE EXPERT SYSTEM

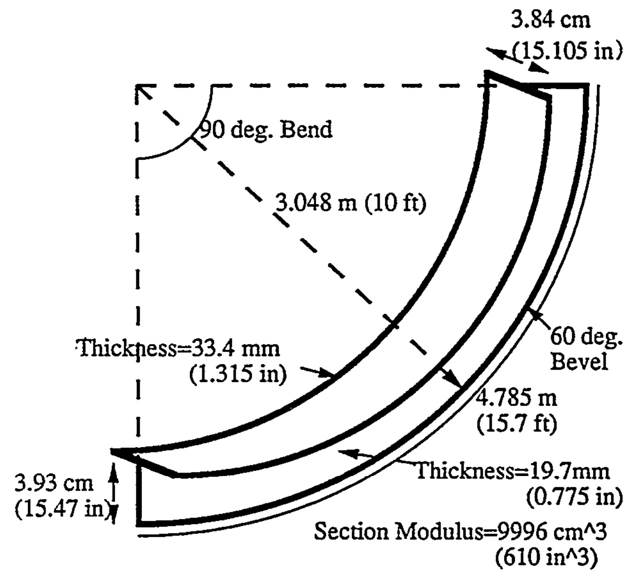
Now that a knowledgebase has been created describing the structural piece-part production domain, the expert system can be used to identify production processes for various structural piece-parts based on part descriptions. The expert system will interactively prompt the user for information it does not have, like part characteristics, as the inference process proceeds.

Following are two examples of how the system identifies production processes for structural piece-parts. The inference processes carried out by the expert system for each part are described. Complete system listings of these two inference processes are also provided in Appendix C.

Part #l

Inference process. Part #l in Figure 2 is a steel rolled T-bar with the toe of the web beveled at 60 degrees, and a part length of about 4.785 m (15.7 ft), which is less than the stock length of 6.096 m (20 ft). The system initially prompts the user for whether the part has shape, whether its edges are beveled, and whether the part is smaller than stock or, if not, whether its area in square feet is less than that of a stock piece. In this way the system can infer whether the part needs to be formed, edge prepped, or cut using Rules 1, 2, 3, 4, and 5. The system then prompts the user for all of the necessary part attribute information that is required to choose the specific shop processes necessary to produce the part using Rules 6-12 (there are too many of these to list individually here; refer to Appendix C for a detailed listing of the complete inference process). Tn this case, the user has specified that Part #l requires a high level of accuracy in part length, roll radius, and bevel angle. The entire data entry and system inference process takes approximately 2.5 minutes.

Solution. The system properly concludes that Part #l requires cutting, edge prep, and forming. The system then concludes that the edge prep method should be the edge planer, PLl, in Bay 2, the part cut method should be the hydraulic band saw, SW2, in Bay 1, and the forming process should be the frame bender, PR5, in Bay 1.



Part#1

Figure 2

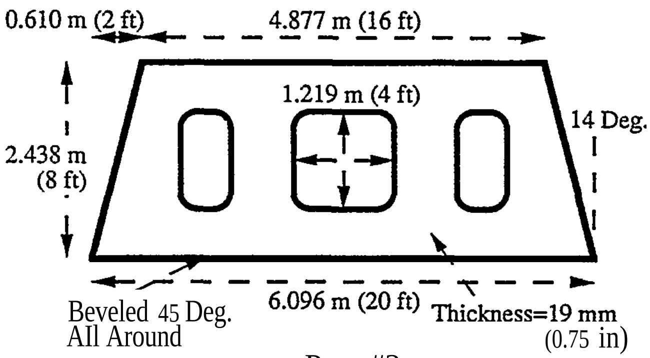
Comments. If the inference process provided in Appendix C is examined in detail, it can be seen that when Rule 9 was testing the 1500 ton press as a possible forming process for Part #l, the rule argument was determined to be "false" because of the tight part roll accuracy specified by the user. Had the user required less roll accuracy, the system might have concluded that the part could be formed on either the frame bender or the 1500 ton press, assuming all other part attributes, such as section modulus maximum, roll radius minimum, etc., met the remaining process limitations of the 1500 ton press.

Part #2

Inference process. Part #2 in Figure 3 is a 19 mm (3/4 in) flat steel plate which is stock length of 6.096 m (20 ft) on its long side, 4.877 m (16 ft) long on the opposite side, 2.438 m (8 ft) wide, symmetrical with two non-parallel straight edges, beveled at 45 degrees on all outer edges, with three cut-outs. Again, the system prompts the user for whether the part has shape, whether its edges are beveled, and whether the part is smaller than stock or, if not, whether its area in square feet is less than that of a stock piece to determine whether the part needs to be formed, edge prepped, or cut. The system then prompts the user for all of the necessary part attribute information that is required to choose the specific shop processes necessary to produce the part (again, refer to Appendix C for a detailed listing of the complete inference process). The entire data entry and system inference process again takes approximately 2.5 minutes.

Solution. The system properly concludes that Part #2 requires cutting, and edge prep. The system then concludes that the edge prep method could be either the edge planer, PLl, in Bay 2, or

the N/C plasma burning process, BR2, in Bay 3. The system also concludes that the part cut method could be either the N/C 2-axes burning process, BRl, or the N/C plasma burning process, BR2, both in Bay 3.



Part #2

Figure 3

Comments. It is only sensible that if a part can be both cut and edge prepped using the same process, in this case the N/C plasma burning process, that process should be the only solution inferred for each of these fabrication needs. *In* this case, however, the rule necessary to make such a decision has not yet been created by the user. Therefore, the expert system must be refined to address this circumstance.

CONCLUSIONS

Expert System Development

Knowledge Acquisition. The process of knowledge acquisition is critical to the successful development of any expert system. Accurate and detailed domain information is an absolute necessity. The system can only be as smart as the developer; the old computer adage, “garbage in, garbage out” still applies.

When developing the rules which represent how a domain works, it is important to get beyond “rules of thumb” that are often quoted by the domain experts to the underlying logic of such rules. For instance, in the example presented in this paper, it would be easy to short-cut all of the comparisons of part attributes to process capabilities by simply creating rules that state that parts with certain characteristics are produced by certain specific processes. These type of rules ignore the underlyingreasons for the decisions being made, and, if used, potential solution options might be missed simply because they had not been recognized previously by the domain experts.

Knowledge Engineering. It takes some practice for a user to learn the language, syntax, and format requirements of a particular expert system shell. However, shells have evolved to the point where anyone can build a functional, if not elegant, expert system. In fact, some expert system shells today allow a user to create knowledgebases graphically using nodes with associated questions and lines of logical inference between nodes. Knowledge engineering for the example knowledgebase used in this paper took a relatively inexperienced user approximately four man-days.

Expert Systems Applications

Although the example expert system application presented in this paper is relatively basic, it still provides sensible and usable solutions for the processes required to produce certain structural piece-parts within the shop that has been defined. The next logical step with this particular application would be to refine the system to address exceptions which are identified in its use, and perhaps to expand the system to include manual processes, blast and paint processes, lay-off processes, and superpart fabrication processes.

Some might argue that the role of the expert system application presented in this paper is identical to the role of group technology in a similar manufacturing environment; that is to use part attributes to generate the production processes required to create that part. In an environment where product types and processes are fairly static over time, it may indeed make more sense to utilize group technology for this purpose because of the static, hard-coded nature of a group technology system. In an environment of rapidly changing and/or very different product types and processes, the flexibility that an expert system provides, allowing simple changes to attribute values and rules, may make the use of an expert system more suitable. The two systems might be complimentary in that an expert system could be used to help identify product families and work cells for a group technology system.

Beyond the identification of production processes, process durations and resource requirements could be identified based on part attributes, leading to potential cost estimating, scheduling, and resource management applications.

The cost estimating process would be ideal for expert systems application because of the level of uncertainty involved in the process, and because of the presence of cost estimating domain experts in most shipbuilding environments. The Australian Department of Defense is known to be exploring this potential application to help engineers develop ship configuration costs for comparison during design.

Constrained real-time scheduling, and resource management processes also seem potentially ideal for expert systems application because of the day-to-day uncertainties associated with these processes in a shipbuilding environment. This type of application is

currently being developed and has proven to be very complex because the scheduling and resource management domain is generally very large. If, however, all relevant domain data is available directly from a database in real time, an expert system can theoretically be developed to accomplish much of the scheduling and resource management process.

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REFERENCES

1. Bentsen, Charles E., "Index Based Management Information Systems: A Study in Structured Operations," NSRP Ship Production Symposium Proceedings, Milwaukee, Wisconsin, August 1990.

2. Logan, Frank A., "Generative Process Planning By Expert Systems," NSRP Ship Production Proceedings, Williamsburg, Virginia, August 1986.

APPENDIX A

System Listing of Objects and Attributes

. . OBJECTS ... of Mark's HD:Papers:Paper. Exprtsys.Plng:Real.Steel.Fab.7/12.kb/'

1co ton punch
inherits from:
cut process

(general (inherited from cut process]

# of axes (inherited from cut process]
[Protection]
values:
= 1 (1.00)

#l of master cut tools [inherited from cut process]
[Protection]

= 1 (1.00)

# of slave cut tools (inherited from cut process]
[Protection]
values:
= 0 (1.00)

angle cut max (deg) (inherited from cut process)
[Protection]
values:
=0(1.00)

Automation Level (inherited from cut process]
[Protection]
values:
= semi (1.00)

cut accuracy (in) (inherited from cut process)
values:
=.01(1.00)

cut configuration (inherited from cut process)
[Protection]
Values:
is single straight (1.00)
is parallel straight (1.00)
is non-parallel straight (1.00)
is hole (1.00))

cut length max (h)(inherited from cut process]

Values:
= .75 (1.00)

cut location (inherited from cut process)
[Protection]
Values:
is bay 1 (1.00)

cut part depth max (in) (inherited from cut process]
[Protection]
Values:
=4 (1.00)

cut part length max (ft) (inherited from cut process]
[Protection]
values:
= 40 (1.00)

cut part width max (ft) (inherited from cut process]
[Protection]
Values.:
= .75 (1.00)

cut routing cod.3 (inherited from cut process]
values:
=sh2(1.00)

hole diameter max (in) (inherited from cut process]
[Protection]
Values:
=3(1.00)

marl cut thickness max. alum (in) (inherited from cut process]
[Protection]
Values:
=1 (1.00)

marl cut thickness max. steel (in) (inherited from cut process)

values:
=.375 (1.00)

12 Foot Roll
inherits from:
form process

(general) (inherited from form process]

form accuracy (in. radius). (inherited from form process]
[Protection]
Values:
= .2 (1.00)

forming location (inherited from form process]
[Protection]
values:
is bay 3 (1.00)

forming part depth max (In) (inherited from form process]
[Protection]
Values
=6(1.00)

forming part length max (ft) (inherited from form process)
[Protection]
values:
=25 (1.00)

forming part width max (ft) (inherited from form process)
[Protection]
Values:
-12 (1.00)

forming routing code [inherited from form process]
[Protection]
Values:
is rl2(1.00)

outsdo radius min (in) (inherited from form process]
[Protection]
Values:
-14 (1.00)

Roll Degrees Max [inherited from form process)
[Protection]
Values:
- 360 (1.00)

section modulus max. alum (in"3) (inherited from form process]
[Protection]

= 157 (1.00)

section modulus max. steel **(in^3)** (inherited from form process]
[Protection]

= 54 (1.00)

web h/t max (inherited from form process]
[Protection]

=0(1.00)

1500 Ton Press
inherits from:
form process

(general) (inherited from form process]

form accuracy (in. radius) (inherited from form process]
[Protection]

- .1 (1.00)

forming location [inherited from form process)
[protection]
values:
is bay 2 (1.00)

toning part depth max (in) (inherited from form process]
[Protection]
values:
= 22 (1.00)

forming part length max (ft) Inherited from form process]
[Protection]
Values:
= 35 (1.00)

forming part width max (ft) (inherited from form process]

values:
=l 20 (1.00)

forming muting code (inherited from form process]
[Protection]
Values:
is pr2 (1.00)

outside radius min (In) (inherited from form process)
[Protection]
Values:
= 22 (1.00)

Roll Degress Max (inherited from form process)
[Protection]

=180 (1.00)

section modulus max. alum (in^3) (inherited from form process)
[Protection]
values`:
- 1044 (1.00)

section modulus max. steel (in^3) [inherited from form process)
[Protection]
Values:
=360 (1.00)

web h/t max (Inherited from form process)
[Protection]
Values:
= 20 (1.00)

2000 Ton Roll
inherits from:
form process

(general) (inherited from form process]

form accuracy (in. radius) (inherited from form process]
[Protection]
values:
= .1 (1.00)

farming location (inherited from form process)
[Protection]
Values:
is bay 2 (1.00)

forming part depth max (in) (inherited from form process)
[Protection]
Values:
=11 (1.00)

forming part length max (ft) (inherited from form process)
[Protection]
Values:
= 40 (1.00)

forming part width max (ft) (inherited from form process)
[Protection)
Values:
= 45 (1.00)

formlng muting code [inherited from form process)
[Protection]
Values:
is rll (1.00)

outside radius min (in) (inherited from form process)
[Protection]
Values:
= 24 (1.00)

Roll Degrees Max (inherited from form process)
[Protection]
Values:
= 180 (1.00)

section modulus max. alum in^3) (inherited form form process)
[Protection]
Values:
=4176 (1.00)

section modulus max. steel (in^3) [inherited from form process]
[Protection]

= 1440 (1.00)

web h/t mu (inherited from form process)
(Protection]
Values:
= 0(1.00)

250 Ton Press
inherits from:
form process

(general) [inherited from form process]

form accuracy (in. radius) (inherited from form process)
[Protection]
values:
= .2 (1.00)

forming location (inherited from form process)

Values:
is bay 3 (1.00)

forming part depth max (in) inherited from form process)
[Protection]
Values:
= 12 (1.00)

forming part length max (ft) (inherited from form Process)
protection]
Values:
= 20 (1.00)

forming part width max (Ft) (inherited from form process)
[Protection]
Values:
=4(1.00)

forming muting code (inherted from form process)
[Protection]
Values:
is pr6 (1.00)

outside radius min (in) (inherited from form process)
[Protection]
Values:
= 17 (1.00)

Roll Degrees Max (inherited from form process)
[Protection]
Values:
= 180 (1.00)

section modulus max. alum (in^3) (inherited from form process)
[Protection]
Values:
= 52 (1.00)

section modulus max. steel (in^3) inherited from form process]
[Protection]
values:
= 18 (1.00)

web h/t max (inherited from form process)
[Protection]
Values:
= 22 (1.00)

37.5 Ton Press
inherits from:
form process

(general) (inherited from form process)

form accuracy (in. radius) (inherited from form process)
[Protection]
Values:
= .1 (1.00)

forming location (inherited from form process)
[Protection]

is bay 3 (1.00)

forming part depth max (in) inherited from form process)
[Protection]
values:
=4 (1.00)

forming part length max (ft) [inherited from form process]
[Protection]
values:
= 8 (100)

forming part width max (ft) (inherited from form process)

values:
=1 (1.00)

forming muting code [inherited from form process]
[Protection]
values:
is pn (1.00)

outside radius min (in) (inherited from form process)
[Protection]
Values:
=4 (1.00)

Roll Degrees Max (inherited from form process)
[Protection]

=360 (1.00)

Section modulus max. alum in^3) inherited from form process)
[Protection]

= 23 (1.00)

section modulus max. steel (in^3) [inherited from form process]
[Protection]

= 8 (1.00

web h/t max (inherited from form process)
[Protection]

= 20 (1.00)

60 Ton Cold Press
inherited from:
form process

(general) (inherited form form process)

form accuracy (in. radius) (inherited from form process)
[Protection]
values:
= .I5 (1.00)

forming location (inherited from form process)
[protection]
Values:
is bay 1 (1.00)

forming part depth max (in) (inherited from form process)
[Protection]
Values:
= 17 (1.00)

forming part length max. (ft) (inherited from form process)
[Protection]
Values:
= 20 (1.00)

forming part width max (ft) (inherited from form process)
[Protection]
Values:
= 5 (1.00)

forming muting code (inherited from form process}
[Protection]
Values:
is pr7 (1.00)

outside radius min (in) (inherited from form process]
[Protection]
Values:
- 0 (1.00)

Roll Degrees Max (inherited from form process]
[Protection]
Values:
=0 (1.00)

section modulus max. alum (in^3] [inherited from form process)
[Protection]
Values:
= 35 (1.00)

section modulus max. steel :n^3: (inherited from form process)
[Protection]
values:
= 12 (1.00)

web h/t max (inherited from form process)
[Protection]
values:
=24 (1.00)

600 Ton Press
inherits from:
form process

(general) (inherited from form process)

form accuracy (in. radius) (inherited from form process)
[Protection]
Values:
= .1 (1.00)

forming location [inherited from form Process]
[Protection]
Values:
is bay 2 (1.00)

forming part depth max (in) (inherited from form process)
[Protection]
Values:
=15 (1.00)

forming part length max (ft) (inherited from form process)
[Protection]
Values:
=17 (1.00)

forming part width max (f) (inherited from form process]
[Protection]
Values:
= 12 (1.00)

forming routing code (inherited from form process)
[Protection]
Values:
Is pr4 (1.00)

outside radius min (in) (inherited from form process)
[Protection]

= I5 (1.00)

Roll Degrees Max (inherited form form process)
(Protection)
Values:
=180 (1.00)

section modulus max. alum (in'3) (inherited from form process)
[Protection]
values:
= 278 (1.00)

section modulus max, steel (in^3) [inherited from form process)
[Protection]
values:
= 96 (1.00)

web h/t max (inherited from form process]
[Protection)
values:
=20 (1.00)

bandsaw
inherits from:
cut process

(general) [inherited from cut process]

# of axes [inherited from cut process)
[Protection]

= 1 (1.00)

# of master cut tools (inherited from cut process)
[Protection]
Values:
= 1 (1.00)

# of slave cut tools [inherited from cut process]
[Protection]

= 0 (1.00)

angle cut max (deg) (inherited from cut process)
[Protection]
values:
= 45 (1.00

Automation Level [inherited from cut process]
[Protection]
values:
= semi (1.00)

cut accuracy (in) [inherited from cut process]
[Protection]
Values:
= .05 (1.00)

cut configuration [inherited from cut process]
[Protection]
values:
is non-parallel straight (1.00)
is parallel straight (1.00)
is single straight (1.00)

cut length max (h) (inherited from cut process)

Values:
-3(1.00)

cut location (inherited from cut process)
(Protection]
values:
is bay 3 (1.00)

cut part depth max (in) [inherited from cut process)
[Protection)
Values:
-4(1.00)

cut part length max (h) (inherited from cut process)
[Protection]
Values:
- 4 (1.00)

cut part width max (h) [inherited from cut process)
(Protection)
Values:
-3(1.00)

cut routing code [inherited from cut process)
[Protection]
Values:
is SW1 (1.00)

hole diameter max [in) (inherited from cut process)
[Protection]
values:
-0(1.00)

man cut thickness max, alum (in) (inherited from cut process)
[Protection]
values:
= 3 (1.00)

marl cut thickness max, steel (in) [inherited from cut process]
[Protection]
Values:
=1 (1.00)

Brake Press
inherits from:
form process

(general) (inherited from form process)

form accuracy (in. radius) [inherited from form process]
[Protection]
values:
- .15 (1.00)

f o r m i n g location (inherited from form process)
Protection
values:
is bay 3 (1.00)

forming part depth max (in) (inherited from form process)
[Protection]
values:
-15 (1.00)

forming part length max (h) [inherited from form process)
[Protection)
values:
-35 (1.00)

forming part **width** max (h) [inherited from form process)
[Protection)
values:
-12 (1.00)

forming routing cods [inherited from form process]
[Protection]
values:
is pr1 (1.00)

outside radius min (In) [inherited from form process]
[Protection]
values:
- 12 (1.00)

Roll Degrees Max [inherited from form process]
[Protection]
values:
- 180 (1.00)

section modulus max. alum (in 3) [inherited from form process)
(Protection)
values:
- 213 (1.00)

Section modulus max, steel (in 3) [inherited from form process)
[Protection)
Values:
-74 (1.00)

web h/t max [inherited from form process)
[Protection)
values:
-20 (1.00)

contour band saw
inherits from:
cut process

(general) (inherited from cut process)

# of axes [inherited from cut process)
[Protection]
values:
-2 (1.00)

# of master cut tools (inherited from cut process)
[Protection]
Values:
-1 (1.00)

# of slave cut tools [inherited from cut process)
[Protection]
values:
- 0 (1.00)

angle cut rnax (deg) [inherited from cut process]
[Protection]
values:
- 45 (1.00)

Automation Level [inherited from cut process)
[Protection]
values:
- semi (1.00)

cut accuracy (in) [inherited from cut process)
[protection]
values:
= .02 (1.00)

cut configuration [inherited from cut process]
[Protection]
Values:
is contour (1.00)
is non-parallel staight (1.00)
is parallel straight (1.00)
is single straight (1.00)

cut length max (h) [inherited from cut process)
[Protection)
values:
=2(1.00)

cut location [Inherited from cut process]
[Protection]
values:
is bay 3 (1.00)

cut part depth max (in) [inherited from cut process]
[protection)
values:
= 12 (1.00)

cut part length max (ft) [inherited from cut process]
[Protection]
Values:
=8(1.00)

cut part width max (ft) [inherited from cut process]
[Protection]
values:
=2(1.00)

cut routing code [inherited from cut process]
[Protection]
values:
is sw3 (1 .00)

hole diameter max (in) [inherited from cut process]
[Protection]
values:
=0 (1.00)

marl cut thickness max. alum (in) [inherited from cut process]
[Protection]
values:
= 6 (1.00)

marl cut thickness max. steel (in) [inherited from cut process)
[Protection]
values:
= 2 (1.00)

cut process
is inherited by:
drill #2
100 ton punch
band saw
contour tend saw
drill #1
Flame Plane 1
Flame Plane 2
hydraulic tend saw
N/C 2-Axis
N/C Plasma
shear

(general)

#Of axes

# of master cut tools

# of slave cut tools

angle cut max (deg)

Automation Level

cut accuracy (in)

cut configuration

cut length max (ft)

cut location

cut part depth max (in)

cut part length max (ft)

cut part width max (ft)

cut routing code

hole diameter max (in)

marl cut thickness max. alum (in)

marl cut thickness max. steel (in)

drill #1
inherits from:
cut process

(general) [inherited from cut process)

f a x e s [inherited from cut process]
[Protection]
values:
=1 (1.00)

# of master cut tools [inherited from cut process]
[Protection]
values:
-1 (1.00)

# of slave cut tools {inherited from cut process]
[Protection]
values:
= 0 (1.00)

angle cut max (deg) (inherited from cut process)
[Protection]
Values:
=0 (1.00)

Automation Level [inherited from cut process)
[Protection]
values:
= semi (1.00)

cut accuracy [in) (inherited from cut process)

{Protection]
values:
= .005 (1.00)

art configuration (inherited from cut process)
[Protection]
Values:
is hole (1.00)

art length max (ft) [inherited from cut process]

Values:
=25 (1.00)

cut location (inherited from cut process)
[Protection]
values:
is bay 1 (1.00)

cut part depth max (in) [inherited from cut process)
[Protection]
Values:
= 15 (1.00)

cut part length max (ft) [inherited from cut process]
[Protection]
Values:
= 25 (1.00)

cut part width max (ft) [inherited from cut process)
[Protection]
values:
=3(1.00)

cut muting code [inherited from cut process}
[Protection]
values:
is dr1 (1.00)

hole diameter max (in) [inherited from cut process]
[Protection]
values:
= 3 (1.00)

marl cut thickness max. alum (in) (inherited from cut process]
[Protection]
values:
=6(1.00)

marl cut thickness max. steel (in) [inherited from cut process]
[Protection]
values:
=6(1.00)

drill #2
inherits fro":
cut process

(general) (inherited from cut process)

#l of axes [inherited from cut process]
[Protection]
values:
= 1 (1.00)

# of master cut tools [inherited from cut process]
[Protection]
Values:
= 1 (1.00)

# of slave cut mob [inherited from cut process]
[Protection]
values:
= 0 (1.00)

angle cut max (dog) [inherited from cut process]

[Protection]
values:
=0(1.00)

Automation Level [inherited from cut process]
[Protection)
Values:
=semi (1.00)

cut accuracy (in) (inherited from cut process)
[protection)
values:
= .005 (1.00)

an configuration {inherited **from** cut process)
[Protection]
values:
is hole (1.00)

cut length max (ft) [inherited from cut process]
Protection
Values:
= 35 (1.00)

cut location [inherited fro" cut process)
[Protection)
values:
is bay 3 (1.00)

cut part depth max (in) (inherited from cut process]
[Protection]
values:
= 10 (1.00)

cut part length max (ft) [inherited from cut process)
[Protection]
values:
= 35 (1.00)

cut part width max (ft) (inherited from cut process]
[Protection]
values:
=12 (1.00)

cut routing code [inherited from cut process]
[Protection]
Values:
is dr2 (1.00)

hole diameter max (in) [inherited from cut process]
[Protection]
values:
=4 (1.00)

marl cut thickness max. alum (in) (inherited from cut process]
[Protection]
values:
=6(1.00)

man cut thickness max. steel (in) (inherited from cut process)
[Protection]
values:
= 6 (1.00)

edge planer
inherits from:
edge prep process

(general) (inherited from edge prep process]

bevel accuracy (deg) (inherited from **edge** prep process]
[Protection]
values:
= 2 (1.00)

bevel Configuration (inherited from edge prep Process)

[Protection]
values:
is single straight (1.00)
is parallel straight (1.00)
is non-parallel straight (1.00)

Bevel Degrees Max [inherited from edge prep process]
[Protection]
values:
=80 (1.00)

edge prep length max (ft) (inherited from edge prep process]
[Protection]
values:
=36 (1.00)

edge prep location (inherited from edge prep process)
[Protection]
values:
is bay 2 (1.00)

edge prep PM depth max (in) (inherited from edge prep process)
[Protection]
Values:
= 18 (1.00)

edge prep part length max (ft) (inherited from edge prep process]
[Protection]
Values:
=36 (1.00)

edge prop pan width max (ft) (inherited from edge prep process)
[Protection]
values:
= 20 (1.00)

edge prep routing code (inherited from edge prep process)
[Protection]
values:
Is pl1 (1.00)

edge pop thickness max. alum (in) (inherited from edge prep process]
[Protection]
values:
=4 (1.00)

edge prep thickness max. steel (in) (inherited from edge prep process)
[Protection]
Values:
=4(1.00)

edge prep process
is inhented by:
Flame Plane 1
N/C Plasma
edge planer

(general)

bevel accuracy (dog)

bevel configuration

Bevel Degrees Max

edge prep length max (lt)

edge prep location

edge pep part depth max (in)

edge prep pan length max (ft)

edge prep part width max (ft)

edge prep routing code

edge prep thickness max. alum (in)

edge prep thickness max. steel (In)

Flame Plane:
inherits from:
cut process
edge prep process

(general) {inherited from edge prep process}

(general) {inhented from cut process}

# of axes {inherited from cut process}
[Protection]
values:
= 1 (1.00)

# of master cut mob (inherited from cut process)
[Protection]
values:
= 11 (1.00)

# of slave cut toots {inherited from cut process}
[Protection]
values:
=0(1.00)

angle cut max (deg) (inherited from at process)
[Protection]
values:
=0(1.00)

Automation Level [inherited from cut process]
[Protection]
Values:
is semi (1.00)

bevel accuracy (deg) [inherited from edge prep process]
[Protection]
values:
=2(1.00]

bevel configuration (inherited from edge prep process]
[Protection]
values:
is single straight (1.00)
is parallel staright (1.00)

Bevel Degrees Max (inherited from edge prep process]
[Protection]
values:
= 60 (1.00)

cut accuracy (in) (inherited from cut process)
[Protection]
Values:
= .05 (1.00)

cut configuration (inherited from at process)
[Protection]
values:
is parallel staight (1.00)
is single straight (1.00)

cut length max (ft) (inherited hum cut process]
[protection]
Values:
=50 (1.00)

at location (inherited from cut process)
[Protection]
Values:
is bay 2 (1.00)

cut part depth max (in) (inherited from cut pocess]
[Protection]
values:
= 10 (1.00)

cut part length max (ft) [inherited from cut process]
[Protection]
Values:
= 50 (1.00)

cut part width max (ft) (inherited from cut process]
[Protection]
Values:
= 16 (1.00)

cut routing code (inherited from cut process]
[Protection]

is $1 (1.00)

edge prep length max (ft) inherited from edge prop process]
[protection]
Values:
= 50 (1.00)

edge prep location (inherited from edge prep process]
[Protection]

is bay 2 (1.00)

edge prep part depth max (in) (inherited hum edge prop process]
[Protection]
Values:
- 10 (1.00)

edge prep part length max (ft) (inherited from edge prep process]
protection]
Values:
-50 (1.00)

edge prep part width max (fh) (inherited from edge prep process]
]Protection]
Values:
ı16 (1.00)

edge prep routing code (inherited from edge prep process]
[Protection]
values:
is fp1 (1.00)

edge pep thickness max. alum (in) (inherited from edge prep process]
[Protection]
values:
= 0 (1.00)

edge prep thickness max. steel (in) (inherited from edge prep process]
[Protection]
values:
= 6 (1.00)

hole diameter. max (in) (inherited from cut process]
[Protection]
-

-O(1.00)

mail cut thickness max. alum (in] (inherited from cut process]
[Protection]
Values:
-0(1.00)

man cat thickness max. steel (in] (inherited from cut process]
[Protection]
values:
-6(1.00)

Flame Plane 2

inherits from:
cut process

. (general) (inherited from cut process]

# of axes (inherited from cut process]
[Protection]
values:
= 1 (1.00)

# of master cut tool5 (inherited from cut process)
[Protection]

-2(l.00)

x of stave cut too!3 (inherited frorn cut process]
[Protection]
Values:
-0(1.00)

angle cut max (deg) (inherited from cut procees)
(Protection)
Values:
.0(1.00)

Automation Level (inherited from cut process)
[Protection]
Values:
is semi (1.00]

cut accuracy (in) (inhoritod from cut process)
[Protection]
Values:
- .03 (1.00)

cut configuration (Inherited from cut process)
(Protection)
Values:
is parallel straight (1.00)
is single staight (1.00)

cut length max (ft) (inherited from cut process]
(Protection)
values:
- 50 (1.00)

cut location (inherited from cut process)
[Protection]
values:
is bay 2 (1.00)

cu' part depth max (in] (inherited from cut process)
[Protection]
Values
- 4 (1.00)

cut part length max (ft) (inherited from cut process)
[Protection]
Values:
PM (1.00)

cut part width max (ft) (inherited from cut process)
[Protection]
Values:
= 12 (1.00)

cut routing code (inherited from cut process)
[Protection]

is fp2 (1.00)

hole diameter max (in) (inherited from cut process)
[Protection]
values:
= 0 (1.00)

man cut thickness max. alum (in) (inherited from cut process)'
[protection]
values:
- 0 (1.00)

man cut thickness max. steal (in) (inherited from cut process)
[Protection]
values:
- 4 (1.00)

form process
is inherited by:
12 Foot Roll
250 Ton Press
37.5 Ton Press
60 Ton Cold Press
600 Ton Pross
Brake Press
1500 Ton Press
XI00 Ton Roll
Frame Bender

(general)

from accuracy (in. radius)

forming location

forming part depth max (in)

forming part length max (ft)

forming part width max (ft)

forming routing code

outside radius min (in)

Roll Degrees Max

section modulus max, alum (in^3)

section modulus max. steel (in^3)

web**ht/**max

Frame Bender
inherits from:
form process

(general) (inherited from form process)

form accuracy (in. radius) (inherited from form process)
values:[Protection]

- .05 (1.00)

forming location (Inherited from form process]
[Protection]
values:
is bay 1 (1.00)

forming part depth max (in) (inherited from form process)
[Protection]
values:
- 30 (1.00)

forming part length max (ft) (inherited from form process)
[Protection]
values:
- 40 (1.00)

forming part width max (ft) (inherited from form process]
[Protection]
Values:
- 1.5 (1.00)

forming muting code (inherited from form process]
[Protection]
values:
is **pr5**(1.00)

outside radius min (in) [inherited from form process]
[Protection]
values:
= 60 (1.00)

Roll Degrees Max (inherited from form process]
values: [protection]

= 270 (1.00)

secton modulus max. alum (in^3) (inherited from form process]
values: [Protection]
= 3000 (1.00)

secton modulus max, steel (in^3) (inherited from form process]
[Protection]
values:
= 1000 (1.00)

w e b h / t (inherited from form process]
[Protection]
values:
ı 24 (1.00)

hydraulic band saw
inherits from:
cut process

(general) (inherited from cut process]

# of axes (inherited from cut process]
[Protection]
values:
-1 (1.00)

# of master cut tools (inherited from cut process)
[Protection]
values:
- 1 (1.00)

# of slave cut tools (inherited from cut process]
[Protection]
values:
- 0 (1.00)

angle cut max **(deg)** (inherited from cut process]
[Protection]
values
- 45 (1.00)

Automation Level (inherited from cut process)
[Protection]
values:
is semi (1.00)

cut accuracy (ii) (inherited from cut process)
[Protection]
values:
- .02 (1.00)

cut configuration (inherited from cut process)
[Protection]
values:
is parallel straight (1.00)
is single straight (1.00)
Is non-parallel straight (1.00)

cut length max (ft) (inherited from cut process]
[Protection]
values:
- 1.5 (1.00)

cut location (inherited from cut process]
values: [Protection]
is bay 1 (1.00)

cut part depth mu (in) (inherited from cut process)
[Protection]
values:
- 20 (1.00)

cut part length max (ft) (inherited from cut process)
[Protection]
values:
- 40 (1.00)

cut part width max (ft) (inherited from cut process)
[Protection]
values:
- 1.5 (1.00)

cut routing code (inherited from cut process)
[Protection]
values:
is SW2 (1.00)

hole diameter max (in) (inherited from cut process)
[Protection]
values:
- 0 (1.00)

man cut thickness max, alum (in) (inherited from cut process)
[Protection]
values:
- 6 (1.00)

matl cut thickness max. steel (in) (inherited from cut process]
[Protection]
values:
- 3 (1.00)

NIC 2-Axis
inherits from:
cut process

(general) inherited from cut process]

# of axes (inherited from cut process)
[Protection]
values:
- 2 (1.00)

# of master cut tools (inherited from cut process)
values: [Protection]
- 2 (1.00)

# of slave cut tools (inherited from cut process)
values: [Protection]
- 2 (I . W)

angle cut max (deg) (inherited from cut process]
values: [Protection]
- 360 (1.00)

Automation Level [inherited from cut process)
values: [Protection]
- N/C (1.00)

cut accuracy (in) (inherited from cut process]
[Protection]
values:
- .02 (1.00)

cut configuration (inherited from cut process)
[Protection]
values:
is parallel straight (1.00)
is non-parallel straight (1.00)
is single straight (1.00)
is contour (1.00)
is hole (1.00)

cut length max (ft] [inherited from cut process)
values: [Protection]
- 140 (1.00)

cut location (inherited from cut process]
[Protection]
values:
is bay 3 (1.00)

cut part depth max (in) (inherited from cut process)
[Protection]
values:
- 6 (1.00)

cut part length max (ft) (inherited from cut process)
[Protection]
values:
- 140 (1.00)

cut part width max (ft) (inherited from cut process]
[Protection]
values:
- 16 (1.00)

cut routing code [inherited from cut process]
[Protection]
values:
is **br1** (1.00)

hole diameter max (in) (inherited from cut process]
[Protection]
values:
- 138 (1.00)

matl cut thickness max. alum (in) (inherited from cut process)
[Protection]
values:
- 0 (1.00)

matl cut thickness max, steel (in) (inherited from cut process)
[Protection]
values
- 6 (1.00)

N/C Plasma
inherits from:
cut process
edge prep process

(general) (inherited from edge prep process)

(general) (inherited from cut process]

# of axes (inherited from cut process)
[Protection]
values:
= 3 (1.00)

# of master cut tools (inherited from cut process)
[Protection]
values:
= 2 (100)

# of slave cut tools (inherited from cut process]
[Protection]
values:
= 2 (1.00)

angle cut max (deg) (inherited from cut process)
values: [Protection]
= 360 (1.00)

Automation Level (inherited from cut process)
[Protection]
values:
is N/C (1.00)

bevel accuracy (deg) [inherited from edge prep process)
[Protection]
values:
= .5 (1.00)

bevel configuration (inherited from edge prep process]
[Protection]
values:
is single straight (1.00)
is parallel straight (1.00)
is non-parallel straight (1.00)
is contour (1.00)

Bevel Degrees Max (inherited from edge prep process)
(Protection)
values:
= 70 (1.00)

cut accuracy (in) (inherited from cut process)
values: [Protection]
= .02 (1.00)

cut configuration (inherited from cut process]
[Protection]
values:
is parallel straight (1.00)
is single straight (1.00)
is non-parallel straight (1.00)
is contour (1.00)
is hole (1.00)

cut length max (ft) (inherited from cut process]
values:
= 50 (1.00)

cut location [inherited from cut process]
[Protection]
values:
is bay 3 (1.00)

cut part depth max (in) (inherited from cut process)
values: [Protection]
= 6 (1.00)

cut part length max (ft) (inherited from cut process)
[Protection]
values:
= 50 (1.00)

cut part width max (ft) (inherited from cut process)
[Protection]
values:
= 18 (1.00)

cut routing code (inherited from cut process)
[Protection]
values
is br2 (1.00)

edge prep length max (ft) (inherited from edge prep process)
[Protection]
values:
= 50 (1.00)

edge prep location (inherited from edge prep process)
[Protection]
values:
is bay 3 (1.00)

edge prep part depth max (in) (inherited from edge prep process)
[Protection]
values:
= 6 (1 .00)

edge prep part length max (ft) (inherited from edge prep process]
[Protection]
values:
= 50 (1.00)

edge prep part width max (ft) (inherited from edge prep process]
values: [Protection]
= 18 (1.00)

edge pep routing code (inherited from edge prep process)
[Protection]
values:
is br2 (1.00)

edge prep thickness max. alum (in) (inherited from edge prep process)
values: [Protection]
= 3 (1.00)

edge prep thickness max. stool (in) (inherited from edge prep process)
[Protection]
values:
= .75 (1.00)

hole diameter max (in) (inherited from cut process)
values: [Protection]
= 216 (1.00)

man cut thickness max. alum (in) (inherited from cut process)
[Protection]
values:
= 3 (1.00)

man cut thickness max. steel (in) (inherited from cut process)
[Protection]
values:
= .75 (1.00)

part

angle max var. from 90 dog
[No Auto Values]

area. sq.ft.
automatic values:
is less than stock area, sq.ft.

bevel configuration
automatic values:
is single straight
is parallel straight
is non-parallel straight
is contour

cut configuration
automatic values:
is hole
is single straight
is parallel straight
is non-parallel straight
is contour
is non-parallel straight
is parallel straight
is single straight

cut dimensions accuracy requirement (in)
automatic values:
= .005
= .01
= .05
= .02
= .03

cut location
[No Auto values]

cut method
[No Auto Values]

cut muting code
[No Auto Values]

depth (in)
[No Auto Values]

edge prep location
[No Auto Values]

edge prep method
[No Auto Values]

edge prep routing code
[No Auto Values]

edge/end preparation
automatic values:
is beveled

flange thickness (in)

forming location
[No Auto Values]

forming method
(No Auto Values]

forming routing code
[No Auto Values]

hole cut diameter (in)
[No Auto Values]

length (ft)
[No Auto Values]

man thickness to be cut (in)
[No Auto Values]

material
automatic values:
is alum
is steel

max bevel angle required
[No Auto Values]

max cut length (ft)
[No Auto Values]

max edge prep length (ft)
(No Auto Values]

outside radius (in)
[No Auto Values]

process
[No Auto Values]

roll degrees
[No Auto Values]

roll radius accuracy requirement (in)
automatic values:
= .2
= .1
=.15
=.05

section modulus alum
[No Auto Values]

section modulus steel
[No Auto Values]

shape
automatic values:
is rolled
is knuckled

size
automatic values:
is smaller than stock
is stock
is larger than stock

thickness alum
[No Auto Values]

thickness steel
[No Auto Values]

type
automatic values:
is plate
is shape

web h/t
[No Auto Values]

web thickness (in)

width (ft)
[No Auto Values]

shear
inherits from:
cut process

(general) [inherited from cut process)

# of axes (inherited from cut process)
(Protection]
values:
= 1 (1.00)

# of master cut tools (Inherited from cut process)
[Protection]
values:
= (1.00)

# of slave cut tools (inherited from cut process)
values: [Protection]

= 0 (1.00)

angle cut max (deg) (inherited from cut process)
(Protection]
values:
= 0 (1.00)

Automation Level (inherited from cut process)

values: [Protection]

= semi (1.00)

cut accuracy (in) [inherited from cut process]
[Protection]
values:
= .03 (1.00)

cut configuration (inherited from cut process)
(Protection]
values:
is single straight (1.00)
is parallel straight (1.00)
is nonparallel straight (1.00)

cut length max (ft) (inherited from cut process)
[Protection]
values:
= 10 (1.00)

cul location (inherited from cut process)
[Protection]
values:
is bay 3 (1.00)

cut part depth max (in) (inherited from cut process)
[Protection]
values:
= 6 (1.00)

cut part length max (ft) [inherited form cut process]
[Protection]
values:
= 18 (1.00)

cut part width max (ft) [inherited from cut process]

values: [Protection]
= 10 (1.00)

cut routing code (inherited from cut process)
(Protection]
values:
is sh1 (1.00)

hole diameter max (in) (inherited from cut process)
values: [Protection]

= 0 (1.00)

man cut thickness max, alum (in) (inherited from cut process)
[Protection]
values:
= 1.5 (1.00)

man cut thickness max. steel (in) (inherited from cut process]
[Protection]
values:
= .5 (1.00)

*** OBJECTS ***

APPENDIX B

System Listing of Rules

. ** RULES . . . of Marks HD:Papers:Paper, Exprt.Sys.Plng:Real.Steel.Fab.7/12.kb . . .

RULE #1 priority 50 -
IF -------------------
(1) the part shape is rolled [threshold 0.20]
(2) or the part shape is knuckled [threshold 0.201
THEN ----------------
(1) part process is “form process” [certainty 1.001

RULE #2 priority 50 -
IF -------------
(1) the part edge/end preparation is beveled [threshold 0.201
THEN ----------
(1) part process is “edge prep process” [certainty 1.00]

RULE #3 priority 50 -
IF -------------------
(1) the part size is “smaller than stock” [threshold 0.20]
THEN ---------------
(1) part process is “cut process” [certainty 1.00]

RULE #4 priority 50 -
IF ---------------
(1) the part size is stock [threshold 0.20]
(2) and the part area, sq.ft. is “less than stock area, sq.ft.” [threshold 0.201
THEN ------------------
(1) part process is “cut process” [certainty 1.00]

RULE #5 priority 50 -
IF -----------------
(1) the part size is “larger than stock” [threshold 0.201
THEN ----------------
(1) part process is “fabricate superpart (joining process)” [certainty 1.001

RULE #6 priority 50 -
IF -----------------
(1) the part material is alum [threshold 0.20]
THEN ----------------
(1) part thickness alum = <part I mat’l thickness to be cut (in)> [certainty 1.00]
ELSE ----------------
(1) part thickness alum = 0 [certainty 1.00]
(2) and part section modulus alum = 0 [certainty 1.00]

RULE #7 priority 50 -
I F -------------
(1) the part material is steel [threshold 0.20]
THEN ------------
(1) part thickness steel = <part 1 mat’1 thickness to be cut (in)> [certainty 1.00]
ELSE ---------------
(1) part thickness steel = 0 [certainty 1.00]
(2) and part section modulus steel = 0 [certainty 1.00]

RULE #8 priority 50 -
IF ----------------
(1) the part process is “cut process” [threshold 0.20]
(2) and the part length (ft) <= <cut process I cut part length max (ft)> [threshold 0.20]
(3) and the part width (ft) <= <cut process I cut part width max (ft)> [threshold 0.20]
(4) and the part depth (in) <= <cut process I cut part depth max (in)> [threshold 0.20]
(5) and the part cut dimensions accuracy requirement (in) >= <cut process I cut accuracy (in)> [threshold 0.20]

(6) and the part thickness Steel <= <cut process | mat'l cut thickness max, steel (in)> [threshold 0.20]
(7) and the part thickness alum <= <cut process | mat'| cut thickness max, alum (in)> [threshold 0.20]
(6) and the part hole cut diameter (in) <= <cut process | hole diameter max (in)> [threshold 0.20]
(9) and the part angle max var. from 90 deg <= <cut process | angle cut max (deg)> [threshold 0.20]
(10) and the part cut configuration is <cut process | cut configuration> [threshold 0.20]
(11) and the part max cut length (ft) <= <cut process | cut length max (ft)> [threshold 0.20]

THEN

(1) part cut method is ObjectName(<cut process>) [certainty
(2) and part cut routing code is <cut process | cut routing code> [certainty 1.00]
(3) and part cut location is <cut process | cut location> [certainty 1.00]

RULE #9 priority 50 -

IF

(1) the part process is “form process” [threshold 0.20]
(2) and the part length (ft) <= <form process | forming part length max (ft)> [threshold 0.20]
(3) and the part width (ft) <= <form process | forming part width max (ft)> [threshold 0.20]
(4) and the part depth (in) <= <form process | forming part depth max (in)> [threshold 0.20]
(5) and the part roll radius accuracy requirement (in) >= <form process | form accuracy (in. radius)> [threshold 0.20`]
(6) and the part section modulus steel <= <form process | section modulus max, steel (in^3)> [threshold 0.20`]
(7) and the part section modulus alum <= <form process I section modulus max, alum (in*3)> [threshold 0.20]
(8) and the part outside radius (in) >= <form process I outside radius min (in)> [threshold 0.20]
(9) and the part roll degrees <= <form process I Roll Degrees Max> [threshold 0.20]
(10) and the part web h/t <= <form process | web h/t max> [threshold 0.20]

THEN

(1) part forming method is ObjectName(<form process>) [certainty 1.001]
(2) and part forming routing code is <form process 1 forming routing code> [certainty I.00]
(3) and part forming location is <form process I forming location> [certainty I.00]

RULE #10 priority 50 -

IF

(1) the part process is “edge prep process” [threshold 0.20]
(2) and the part length (ft) <= <edge prep process I edge prep part length max (ft)> [threshold 0.20]
(3) and the part width (ft) <= <edge prep process I edge prep part width max (ft)> [threshold 0.20]
(4) and the part depth (in) <= <edge prep process | edge prep part depth max (in)> [threshold 0.20]
(5) and the part max bevel angle required <= <edge prep process I Bevel Degrees Max> [threshold 0.20]
(6) and the part thickness steel <= <edge prep process I edge prep thickness max, steel (in)> [threshold 0.20]
(7) and the part thickness alum <= <edge prep process I edge prep thickness max, alum (in)> [threshold 0.20]
(8) and the part max edge prep length (ft) <= <edge prep process I edge prep length max (ft)> [threshold 0.20]
(9) and the part bevel configuration is <edge prep process I bevel configuration> [threshold 0.20]

THEN

(1) part edge prep method is ObjectName(cedge prep process>) [certainty 1.00]
(2) and part edge prep routing code is <edge prep process I edge prep routing code> [certainty 1.00]
(3) and part edge prep location is <edge prep process I edge prep location> [certainty I.00]

RULE #11 priority 50 -

IF

(1) the part type is plate [threshold 0.20]

THEN

(1) part web h/t = 0 [certainty 1.00`]
(2) and part mat’l thickness to be cut (in) = <part | depth (in)> [certainty 1.00]

RULE #12 priority 50 -

IF

(1) the part type is shape [threshold 0.20]

THEN

(1) part web h/t = <part | depth (in)> • .94 / <part | web thickness (in)> [certainty I.00]
(2) and part mat'l thickness to be cut (in) = <part I flange thickness (in)> [certainty I.00]

APPENDIX C

System Listing of Inference Process
Part #l

- - - backward inference (all goals) - - -
atlempling lo salisfy goal 'part process'
full lesling rule 1 - largels: 'part
allempting to satisfy goal part shape'
gelling a value from the user for part shape
atlempting to satisfy goal 'part shape'
acting -true on rule 1
part process ls form process [certainty 1.00)
lull testing rule 2 - targets: 'part'
attempting to satisfy goal part edge/end preparation'
getting a value from the user for part edge/end preparation
acting -true- on rule 2
part process is edge prep process [certainly 1.00]
lull lesting rule 3 - targets: 'part'
attempting lo satisfy goal 'part size'
getting a value from the user for part size
acting -true- on rule 3
part process ls cut process [certainty 1.00]
full testing rule 4 - targets: 'part'
attempting lo satisfy goal 'part size'
acting -false- on rule 4
full testing role 5 - largels: 'part'
altempting lo satisfy goal 'part sire'
acting -false- on rule 5
allempting lo salisfy goal 'part edge prep method
lull testing rule 10 - targets: 'pati 'Flame Plane 1'
attempting lo satisfy goal part process'
attempting lo satisfy goal 'part length (ft)
gelling a value from the Úser for part length (II)
altempting to satisfy goal 'Flame Plane 1 edge prep part length rnax (ft)
attempting lo satisfy goal 'part width (ft)
gelling a value from the user for part width (ft)
attempting to satisfy goal 'flame Plane 1 edge prep part width max (ft)
attempting to satisfy goal 'part depth (In)
getting a value from Ihe user for part depth (in)
attempting lo salisfy goal 'Flame Plane 1 edge prep part depth max (in)
acting -false on rule 10
full testing rule 10 - largels: 'Parr WC Plasma'
attempting lo salisfy goal part process'
attempting lo salisfy goal 'part length (ft)
attempting lo satisfy goal 'N/C Plasma edge prep part lenglh max (ft)
attempting IO satisfy goal 'part width (ft)
attempting lo satisfy goal 'N/C Plasma edge prep part widlh max (ft)
attempting lo satisfy goal 'part depth (in)
attempling lo satisfy goal WC Plasma edge prep part depth max (in)
acting -false- on rule 10
full testing rule 10 - targets: part' 'edge planer'
attempting lo satisfy goal part process'
attempting lo satisfy goal 'part length (ft)
attempting lo satisfy goal 'edge planer edge prep part length max (ft)
attempting lo satisfy goal 'part width (ft)
altempting lo satisfy goal 'edge planer edge prep part width max (ft)
attempting lo satisfy goal 'part depth (in)
attempting lo satisfy goal 'edge planer edge prep part depth max (in)
attempting lo satisfy goal 'part max bevel angle required
gelling a value from the user for part max bevel angle required
attempting to satisfy goal 'edge planer Bevel Degrees Max'
attempting lo satisfy goal 'part thickness steel
full testing rule 7 - targets: 'part
attempting 'to satisfy goal 'part material
gelling a value from the user for part material
acting -true- on rule 7
attempting to satisfy goal part marl thickness lo be cut (in)
full testing rule 11 - targets: 'part
attempting to satisfy goal part type'
getting a value from the user for part type
acting -false- on rule 11
full testing role 12 - targets: 'part
attempting lo satisfy goal part type'
acting -true- on rule 12
attempting to satisfy goal part depth (in)
attempting to satisfy goal '`part web thickness (in)
gelling a value from' the user for part web thickness (in)
part web h/l - 18.8 [certainly 1.00]
attempting to satisfy goal 'part flange thickness (in)
gelling a value from the user for part flange thickness (in)
part mart thickness to be cut (in) is 1.315 [certainty 1.00)
part thickness steel is 1.315 [certainty 1.00)
attempting to satisfy goal 'edge planer edge prep thickness max. steel (in1)
attempting to satisfy goal part thickness alum'
full testing rule 6 - targets: 'part'
attempting lo satisfy goal 'part material
acting -false- on rule 6
part thickness alum I 0 [certainty 1.00)
part section modulus alum - 0 [certainly 1.00)
attempting to satisfy goal 'edge planer edge prep thickness max. alum (in)
attempting lo satisfy goal 'part max edge prep lenglh (ft)
getting a value from the user for part max edge prep length (ft)
attempting IO satisfy goal 'edge planer edge prep length rnax (ftI)
attempting to satisfy goal 'part bevel configuration'
gelling a value from the user for part bevel configuration
attempting lo satisfy goal 'edge planer bevel configuration'
acting -true- on rule 10
par1 edge prep method is edge planer [certainly 1.00)
allempllng IO satisfy goal 'edge planer edge prep routing code'
part edge prep muting code ls P11 [cerlainly 1.00]
attempting to satisfy goal 'edge platter edge prep location'
part edge prep location is bay 2 (certainly 1.00)
attempting lo satisfy goal 'part edge prep location'
attempting lo satisfy goal 'part edge prep routing code'
attempting lo satisfy goal 'part cut location'
full testing rule 8 - largels: part' 'drill #2'
attemping to satisfy goal part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'drill #2 cut part length max (ft)
attempting to satisfy goal 'part width (It)
attempting to satisfy goal 'drill #2 cut part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'drill X2 cut part depth max (in)
acting -false- on rule 8
full testing rule 8 - targets: part' '100 ton punch
attempting lo satisfy goal part process'
attempting lo satisfy goal 'part length (ft)
attempting lo satisfy goal '100 ton punch cut part length max (ft)
attempting lo satisfy goal 'part width (ft)
attempting lo satisfy goal '100 ton punch cut part width max (ft)
acting -false- on rule 8
lull testing rule 8 - largels: part 'band saw'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)'
attempting lo satisfy goal 'band saw cut part length max (ft)
acting -false- on role 8
full testing rule 8 - targets: 'part' 'contour band saw'
attempting lo satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting lo satisfy goal 'contour band saw cut part length max (ft)
acting -false- on rule 8
full testing role 8 - targets: part' 'drill #1'
attempting lo satisfy goal part process'
attempting to satisfy goal 'part length (11`)
attempting 14 satisfy goal 'drill #1 cut part length max (ft)
attempting to satisfy goal part width (ft)
attempting lo satisfy goal 'drill #l cut part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting lo satisfy goal 'drill #l cut part depth max (in)
acting -false- on rule 8
full testing rule 8 - targets: 'part 'Flame Plane 1'
attempting lo satisfy goal part process'
attempting lo satisfy goal 'part length (ft)
attempting lo satisfy goal 'Flame Plane 1 cut part length max (ft)
attempting lo satisfy goal 'part widlh (ft)
attempting lo satisfy goal 'Flame Plane 1 cut part width max (ft)
attempting lo satisfy goal 'part depth (in)
attempting lo satisfy goal 'Flame Plane 1 cut part depth max (in)
acting -false- on rule 8
full testing rule 8 - targets: part 'Flame Plane 2'
attempting to satisfy goal part process'
attempting to satisfy goal 'part lenglh (ft)'
attempting to satisfy goal 'flame Plane 2 cut part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal 'Flame Plane 2 cut part width may (ft)
attempting to satisfy goal 'part depth (in)'
attempting to satisfy goal 'Flame Plane 2 cut part depth max (in)
acting -false- on rule 8
full testing rule 8 - targets: 'part' 'hydraulic band saw'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'hydraulic band saw cut part length max (ft)
attempting to satisfy goal 'part widlh (fl)
attempting to satisfy goal 'hydraulic band saw cut part widlh max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'hydraulic band saw cut part depth max (in)
attempting to satisfy goal part cut dimensions accuracy requirement (in)
getting a value from the user for part cut dimensions accuracy requirement (in)
attempting o satisfy goal 'hydraulic band saw cut accuracy (in)

attempting to satisfy goal 'part thickness steel
attempting to satisfy goal 'hydraulic band saw mart cut thickness max. steel (in)
attempting to satisfy goal 'part thickness alum'
attempting to satisfy goal 'hydraulic band saw marl cut thickness max. alum (in)
attempting to satisfy goal 'part hole cut diameter (in)
getting a value from the user for part hole cul diameter (in)
attempting to satisfy goal 'hydraulic band saw hole diameter max (in)
attempting to satisfy goal 'pad angle max var. from 90 deg'
getting a value from the user for part angle max var. from 90 deg
attempting to satisfy goal 'hydraulic band saw angle cut max (deg)
attempting to satisfy goal 'part cut configuration'
gelling a value from the user for part cut configuration
attempting lo satisfy goat 'hydraulic band saw cut configuration'
attempting lo satisfy goal 'part max cut lenglh (ft)
getting a value from the user for part max cut length (ft)
attempting lo satisfy goal 'hydraulic band saw cut length max (ft)
acting -true- on rule a
part cut method is hydraulic band saw [certainly 1.00]
attempting lo salisfy goal 'hydraulic band saw cut routing coda'
part cut routing code is sw2 [certainly 1.00]
attempting to satisfy goal 'hydraulic band saw cut location'
part cut location is bay 1 [certainty 1.00]
full testing rule a - targets: 'part N/C 2-Axis'
attempting to satisfy goat part process'
attempting to satisfy goat 'part length (ft)
attempting to satisfy goal 'N/C OAxts cul part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal 'N/C PAxis cut part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'N/C 2-Axis cut part depth max (in)
acting -false- on rule a
lull testing rule 6 - targets: 'part' 'N/C Plasma'
attempting to satisfy goal 'part process'
attempting to satisfy goat 'part length (ft)
attempting to satisfy goal 'N/C Plasma cut part length max (ft)'
attempting IO satisfy goal 'part widlh (ft)
attempting to satisfy goal 'N/C Plasma cut part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'N/C Plasma cut part depth max (in)
acting -false- on rule a
full testing rule 6 - targets: 'part' 'shear'
attempting to satisfy goal 'part process
attempting to satisfy goat 'part length (ft)'
attempting to satisfy goat 'shear cut part length max (ft)
attemptlng to satisfy goat 'part width (ft)
attempting to satisfy goat 'shear cut part width may (ft)
attempting to satisfy goal 'part depth (in)'
attempting to satisfy goat 'shear cut part depth max (in)
acting -false- on rule a
attempting to satisfy goal 'part cut routing code'
attempting to satisfy goal 'part cut method
attempting lo satisfy goal 'part forming location
full testing rule 9 - targets: 'part '12 Fool Roll
attempting to satisfy goal 'part process'
attempting to satisfy goat 'part length (ft)
attempting to satisfy goal '12 Fool Roll forming part length max (ft)
attempting to satisfy goal part width (ft)
attempting to satisfy goal '12 Foot Roll forming part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal '12 Fool Roll forming part depth max (in)
acting -false- on rule 9
lull testing rule 9 - targets: 'part' '250 Ton Press'
attempting to satisfy goat 'part process'
attempting to satisfy goat 'part length (ft)'
attempting to satisfy goat '250 Ton Press forming part length max (ft)
attempting to satisfy goat 'part width (ft)
attempting to satisfy goal '250 Ton Press forming part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal '250 Ton Press forming part depth max (in)
acting -false- on rule 9
full testing rule 9 - targets: 'part' '37.5 Ton Press'
attempting to satisfy goat 'part process'
attempting to satisfy goat 'part length (ft)
attempting to satisfy goal '37.5 Ton Press forming part length max (ft)
acting -false- on rule 9
full testing rule 9 - targets: 'part' '60 Ton Cold Press'
attempting to satisfy goat 'part process'
attempting to satisfy goal part length (ft)
attempting to satisfy goat '60 Ton Cold Press forming part length max (ft)
attempting to satisfy goal 'part wldlh (ft)
attempting to satisfy goat '60 Ton Cold Press forming part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goat '60 Ton Cold Press forming part depth max (in)
attempting to satisfy goat part roll radius accuracy requirement (in)
gelling a value from the user for part roll radius accuracy requirement (in)
attempting to satisfy goal '60 Ton Cold Press form accuracy (in. radius)
acting -false- on rule 9
full testing rule 9 - targets: 'part' '600 Ton Press'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part lenglh (ft)'
attempting to satisfy goal '600 Ton Press forming part lenglh max (ft)
altempting to satisfy goal 'part width (ft)
attempting to satisfy goal '600 Ton Press forming part widlh max (ft)
attempting to satisfy goat 'part depth (in)
attempting to satisfy goal '600 Ton Press forming part depth max (in)
acting -false- on rule 9
full testing rule 9 - targets: 'part 'Brake Press'
attempting to satisfy goal 'part process'
attempting to satisfy goal part length (ft)
attempting to satisfy goal 'Brake Press forming part lenglh max (ft)
attempting to satisfy goal 'part widlh (ft)
attempting to satisfy goat 'Brake Press forming part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goat 'Brake Press forming part depth max (in)
acting -false- on rule 9
full testing rule 9 - targets: 'part' '1500 Ton Press'
altempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goat '1500 Ton Press forming part lenglh max (ft)
attempting to satisfy goat 'part width (ft)
attempting to satisfy goat '1500 Ton Press forming part width may (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goat '1500 Ton Press forming part depth max (in)
attempting to satisfy goat 'part roll radius accuracy requirement (in)
attempting to satisfy goal '1500 Ton Press form accuracy (In. radius)
acting -false- on rule 9
full testing rule 9 - targets: 'part' '2000 Ton Roll
attempting to satisfy goat 'part process'
attempting to satisfy goat 'part length (ft)
attempting to satisfy goat '2000 Ton Roll forming part length max (ft)
attempting to satisfy goat 'part width (fly
attempting to satisfy goat 2000 Ton Roll forming part width max (ft)
attempting to satisfy goat part depth (in)
attempting to satisfy goat 2000 Ton Roll forming part depth max (in)
acting -false- on rule 9
full testing rule 9 - targets: 'part 'Frame Bender
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)'
attempting to satisfy goal 'Frame Bender forming part length max (ft)
attempting to satisfy goat 'part width (ft)
attempting to satisfy goal 'Frame Bender forming part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goat 'Frame Bender forming part depth max (in)
attempting to satisfy goat 'part roll radius accuracy requirement (in)
attempting to satisfy goat 'Frame Bender form accuracy (in. radius)
attempting to satisfy goat 'part section modulus sleet'
full testing rule 7 - targets: 'part
attempting to satisfy goal part material
acting -true- on rule 7
attempting to satisfy goat 'part marl thickness lo be cut (in)
gelling a value from the user for part section modulus steel
attempting to satisfy goat 'Frame Bender section modulus max. steel (in"3)
attempting to satisfy goat part section modulus alum'
attempting to satisfy goat 'Frame Bender section modulus max. alum (in*3)
attempting to satisfy goal 'part outside radius (in)
getting a value from the user for part outside radius (in)
attempting to satisfy goat 'Frame Bender outside radius min (in)
attempting to satisfy goat 'part roll degrees
getting a value from the user for part roll degrees
attempting to satisfy goal 'Frame Bender Roll Degrees Max'
attempting to satisfy goat 'part web hi?
attempting lo satisfy goal 'Frame Bender web M max'
acting -true- on rule 9
part forming method is Frame Bender [certainly l.OO]
attempting to satisfy goat 'Frame Bender forming routing code'
part forming muting code is pr5 (certainty l.OO]
attempting to satisfy goat 'Frame Bender forming location'
part forming location is bay 1 [certainly 1.00]
attempting to satisfy goat 'part forming routing code'
attempting to satisfy goal 'part forming method
- - - forward inference - - -

the part process
is cul process [certainty l.OO]
is edge prep pmcess [certainly 1.001
is form process [certainty 1.001

the part edge prep method
is edge planer [cartainty 1.00]

Ihe part edge prep localion
is bay 2 [certainty 1.001

Ihe part edge prep routing code
is pll [certainty l.OO]

the part cut location
is bay 1 [certainty 1.00]

the part cut routing code
is sw2 [certainty 1.OO]

the part cut method
is hydraulic band saw [certainty 1.001

lhe part forming location
is bay 1 [certainty 1.001

the part forming routing code
is pr5 [cerlainly 1.001

the part forming melhod
is Frame Bender [certainly 1 .OO]

********** CONCLUSIONS **********

System Listing of Inference Process Part #2

- - - backward inference (all goals) - - -
attempting lo satisfy goal 'part process'
full testing rule 1 - targets: 'part
attempting to satisfy goal 'part shape'
getting a value from the user for part shape
attempting to satisfy goal 'part shape'
acting -unknown- on rule 1
full testing rule 2 - targets: 'part
attempting to satisfy goal 'part edgelend preparation'
getting a value from the user for part edgelend preparation
acting -true- on rule 2
part process is edge prep process [certainty 1.00]
full testing rule 3 - targets: 'part
attempting lo satisfy goal 'part size'
gelling a value from the user for part she
acting -true- on rule 3
par1 prccess is cut process (certainly 1.001
full testing rule 4 - targets: 'part
attempting to satisfy goal 'part size'
acting -false- on rule 4
full testing rule 5 - targets: *'pati*
attempling to satisfy goal part size'
acting -false- on rule 5
attempting to satisfy goal 'part edge prep method
full testing rule 10 - targets: 'part' 'edge planer'
attempting to sallsfy goal 'part process'
altempling lo satisfy goal 'part length (ft)
getting a value from the user for part lenglh (ft)
attempting to satisfy goal 'edge planer edge prep part length max (ft)
attempting to satisfy goal part width (ft)
getting a value from the user for part width (ft)
attempting to satisfy goal 'edge planer edge prep part width max (ft)
attempting to satisfy goal 'part depth (in)
getting a value from the user for part depth (in)
attempting to satisfy goal 'edge planer edge prep part depth max (in)'
attempting to satisfy goal 'part max bevel angle required
getting a value from the user for part max bevel angle required
attempting to satisfy goal 'edge planer Bevel Degrees Max'
attempting to satisfy goal 'part thickness steer
full testing rule 7 - targets: 'part'
attempting to satisfy goal 'part material
getting a value from the user for part material
acting -true- on rule 7
attempting to satisfy goal 'part matl thickness lo be cut (in)
full testing rule 11 - targets: part
attempting to satisfy goal part type'
gelling a value from the user for part type
aCting -true on rule 11
part web h/t = 0 [certainty 1.00]
attempting to satisfy goal 'part depth (in)'
part marl thickness to be cut (in) is .75 [certainty 1.00]
full testing rule 12 - targets: 'part
attempting to satisfy goal 'part type'
acting -false- on rule 12
part thickness sleel is .75 [cerlalnty 1.00]
attempting to satisfy goal 'edge planer edge prep thickness max. steel (in)
attempting to satisfy goal part thickness alum'
full testing rule 6 - targets: 'part'
attempting to satisfy goal 'part material
acting -false- on rule 6
part thickness alum - 0 [certainty 1.00]
part section modulus alum = 0 [certainty 1.00]
attempting to satisfy goal 'edge planer edge prep thickness max. alum (in)
attempting to satisfy goal 'part max edge prep length (ft)
getting a value from the user for part max edge prep length (ft)
attempting to satisfy goal 'edge planer edge prep length max (ft)
attempting to satisfy goal 'part bevel configuration
getting a value from the user for part bevel configuration
attempting to satisfy goal 'edge planer bevel configuration'
acting-true- on rule 10
part edge prep method is edge planer [certainly 1.00]
attempting to satisfy goal 'edge planer edge prep routing code'
part edge prep rouling code is p11 [certainty 1.00]
attempting to satisfy goal 'edge planer edge prep location'
part edge prep location is bay 2 [certainly 1.00]
full testinagrule 10 - targets: 'part' 'Flame Plane 1'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satlsfy goal 'Flame Plane 1 edge prep part length max (ft)
attempting to satisfy goal 'part widlh (ft)
attempting to satisfy goal 'Flame Plane 1 edge prep part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'Flame Plane 1 edge prep pert depth max (In)
altempting to satisfy goal 'part max bevel angle required'
attempting to satisfy goal 'Flame Plane 1 Bevel Degrees Max'
attempting to satisfy goal 'part thickness steel
attempting to satisfy goal 'flame Plane 1 edge prep thickness max. steel (in)
attempting to satisfy goal 'part thickness alum'
attempting to satisfy goal 'Flame Plane 1 edge prep thickness max. alum (in)
attempting to ***satisfy*** goal part ***max*** edge prep ***length (lt)***
attempting to satisfy goal 'flame Plane ***1*** edge prep length max (fly
attempting to satisfy goal 'part bevel configuration'
attempting to satisfy goal 'Flame Plane 1 bevel configuration'
acting -false- on rule 10
full testing rule 10 - targets 'part' 'N/C Plasma'
attempting to satisfy goal 'part process'
attemtinf to satisfy goal 'part length (ft)
attempting to satisfy goal N/C plasma edge prep part length max (II)
attempting to satisfy goal part width (ft)I
attempting to satisfy goal part Plasma edge prep part width mak (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'N/C Plasma edge prep part depth max (in)
attempting to satisfy goal 'part max bevel angle required'
attempting to salMy goal 'N/C Plasma Bevel Degrees Max'
attempting to satisfy goal 'part thickness steel
attempting to satisfy goal WC Plasma edge prep thickness max. steel (in)
attempting to satisfy goal part thickness alum'
attempting to satisfy goal 'N/C Plasma edge prep thickness max. alum (in)
attempting to satisfy goal 'part max edge prep length (ft)
attempting to satisfy goal 'N/C Plasma edge prep length max (ft)
attempting to satisfy goal 'part bevel configuration'
attempting ***to*** satisfy goal WC Plasma bevel configuration'
acting -true- on rule 10
part edge prep method is NE Plasma [certainty 1.00]
attempting to satisfy goal N/C Plasma ***edge prep*** routing **code'**
part edge prep routing code is br2 [certainty 1.00]
attempting to satisfy goal WC Plasma edge prep lodrion'
part edge prep location is bay 3 [certainty 1.00]
attempting to satisfy goal 'part edge prep location'
attempting to satisfy goal 'part edge prep routing code'
attempting to ***satisfy*** goal ***'part cut*** location
lull testing rule a - targets 'part' 'drill #2'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'drill #2 cut part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal 'drill #2 cut part width max (ft)
attempting to satisfy goal part depth (in)
attempting to satisfy goal 'drill #2 cut part depth max (In)
attempting to satisfy goal 'part cut dimensions accuracy requirement (in)
getting a value from the user for part cut dimensions accuracy requirement (in)
attempting to satisfy goal 'drill #2 cut accuracy (in)
attempting to satisfy goal 'part thickness sleet
attempting to satisfy goal 'drill #2 man cut thickness ***max.*** steel (in)
attempting to satisly goal part thickness alum'
attempting to satisfy goal 'drill man cut thickness max. alum (in)
attempting to satisfy goal part hole cut diameter (in)
getting a value from the user for part hole cut diameter (in)
attempting to satisfy goal 'drill #2 hole diameter max (in)
acting -false- on rule a
full testing rule 8 - largest 'Part '100 ton punch'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (II)
attempting to satisfy goal '100 ton punch cut part lenglh max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal '100 ton punch cut part width max (ft)
acting -false- on rule a
lull testing rule 8 - targets: 'part' 'band saw'
attempting to satisfy goal part process
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal band saw cut part lenglh max (ft)' -
acting -false on rule 8
lull testing rule 8 - targets: 'part' 'contour band saw'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)' *
attempting to satisfy goal 'contour band saw cut part length max (ft)'
acting -false- on rule a

full testing rule 8 - targets: 'part 'drill #1'
attempting to satisfy goat 'part process'
attempting to satisfy goal 'part lenglh (ft)
attempting to satisfy goal 'drill #1 cut part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting lo satisfy goal 'drill #1 cut part width max (ft)
acting -false- on rule 8
lull testing rule 8 - targets: part' 'Flame Plane 1'
attempting to satisfy goat 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'Flame Plane 1 cut part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal 'Flame Plane 1 cut part width max (ft)
attempting to satisfy goal 'part depth (in)
attempting to satisfy goal 'Flame Plane 1 cut part depth max (in)
attempting to satisfy goat part cut dimensions accuracy requirement (in)
attempting to satisfy goal 'Flame Plane 1 cut accuracy (in)
acting -false- on rule 8
full testing rule 8 - targets: 'part' 'Flame Plane 2'
attempting to satisfy goat 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'Flame Plane 2 cut part lenglh max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal 'Flame Plane 2 cut part widlh max (ft)
attempting to satisfy goal 'part depth (in)'
attempting to satisfy goat 'flame Plane 2 cut part depth max (in)
attempting to satisfy goat 'part cut dimensions accuracy requirement (in)
attempting to satisfy goat 'Flame Plane 2 cut accuracy (in)
attempting to satisfy goat 'part thickness steel
attempting to satisfy goal 'Flame Plane 2 man cut thickness max. steel (in)
attempting to satisfy goal part thickness alum'
attempting to satisfy goat 'flame Plane 2 man cut thickness max. alum (in)'
attempting to satisfy goal 'part hole cut diameter (in)
attempting to satisfy goal 'flame Plane 2 hole diameter max (in)
acting -false- on rule 8
full testing rule 8 - targets: 'part' 'hydraulic band saw'
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'hydraulic band saw cut part length max (ft)
attempting to satisfy goal part width (ft)
attempting to satisfy goat 'hydraulic band saw cut part width max (ft)
acting -false- on rule 8
full testing rule 8 - targets: 'part' 'N/C 2-Axis
attempting to satisfy goat 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'N/C 2-Axis cut part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goat 'N/C 2-Axis cut part width max (ft)
attempting to satisfy goal 'part depth (in)'
attempting to satisfy goal 'N/C 2-Axis cut part depth max (in)
attempting to satisfy goat 'part cut dimensions accuracy requirement (in)
attempting to satisfy goat N/C 2-Axis cut accuracy (in)
attempting to satisfy goat 'part thickness steel
attempting to satisfy goal N/C 2-Axis mat'l cut thickness max. steel (in)
attempting to satisfy goal 'part thickness alum'
attempting to satisfy goal 'N/C 2-Axis mat'l cut thickness max. alum (in)
attempting to satisfy goal 'part hole cut diameter (in)
attempting to satisfy goal N/C 2-Axis hole diameter max (in)
attempting to satisfy goal 'part angle max var. from 90 deg'
gelling a value from the user for part angle max var. from 90 deg
attempting to satisfy goal N/C 2-Axis angle cut max (deg)
attempting to satisfy goal 'part cut configuration'
getting a value from the user for part cut configuration
attempting to satisfy goat 'N/C 2-Axis cut configuration'
attempting to satisfy goal 'part max cut length (ft)
gelling a value from the user for part max cut length (ft)
attempting to satisfy goal 'N/C 2-Axis cut length max (ft)
acting -true- on rule 8
part cut method is N/C 2-Axis [certainly 1.00]
attempting to satisfy goal N/C 2-Axis cut routing code'
part cut routing code is br1 [certainly 1.00]
attempting to satisfy goal 'N/C 2-Axis cut location
part cut location is bay 3 [certainly 1.00]
full testing rule 8 - targets: 'part' 'N/C Plasma'
attempting to satisfy goat 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'N/C Plasma cut part length max (ft)
attempting to satisfy goal 'part width (ft)
attempting to satisfy goal N/C Plasma cut part width max (ft)
attempting to satisfy goat 'part depth (in)'
attempting to satisfy goat N/C Plasma cut part depth max (in)
attempting to satisfy goat 'part cut dimensions accuracy requirement (in)
attempting to satisfy goal 'N/C Plasma cut accuracy (in)
attempting to satisfy goat 'part thickness steel'
attempting to satisfy goal N/C Plasma marl cut thickness max. steel (in)
attempting to satisfy goal 'part thickness alum'
attempting to satisfy goal 'N/C Plasma mat'1 cul thickness max. alum (in)
attempting to satisfy goal 'part hole cut diameter (in)
attempting to satisfy goal 'N/C Plasma hole diameter max (in)
attempting to satisfy goal 'part angle max var. from SO deg'
attempting to satisfy goal 'N/C Plasma angle cut max (deg)
attempting to satisfy goal 'part cut configuration'
attempting to satisfy goal 'N/C Plasma cut configuration'
attempting to satisfy goal 'part max cut length (ft)
attempting to satisfy goal 'N/C Plasma cut length max (ft)
acting -true- on rule 8
part cut method is N/C Plasma [certainty 1.00]
attempting to satisfy goal N/C Plasma cut routing code'
part cut routing code is br2 [certainly 1.00]
attempting to satisfy goal 'N/C Plasma cut location'
full testing rule 8 - targets: 'part' 'shear
attempting to satisfy goal 'part process'
attempting to satisfy goal 'part length (ft)
attempting to satisfy goal 'shear cut part length max (ft)
acting -false- on rule 8
attempting to satisfy goal 'part cut routing code'
attempting to satisfy goat 'part cut method'
attempting to satisfy goal 'part forming location'
lull testing rule 9 - targets: part '12 Fool Roll'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '250 Ton Press'
attempting to satisfy goal 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '37.5 Ton Press'
attempting to satisfy goat 'part process
acting -false- on rule 9
full testing rule 9 - targets: 'part' '60 Ton Cold Press'
attempting to satisfy goat 'part process
acting -false- on rule 9
full testing rule 9 - targets: 'part' '600 Ton Press'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' Brake Press'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' 'Frame Bender
attempting to satisfy goal 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '1500 Ton Press'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '2000 Ton Roll'
attempting to satisfy goat 'part process'
acting -false- on rule 9
attempting to satisfy goat 'part forming routing code'
lull testing rule 9 - targets: 'Part '12 Foot Roll
attempting to satisfy goal 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '250 Ton Press'
attempting to satisfy goat 'part process.'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '37.5 Ton Press.'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'Part '60 Ton Cold Press'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'Part '600 Ton Press'
attempting to satisfy goal 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' 'Brake Press'
attempting to satisfy goal 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' 'Frame Bender'
attempting to satisfy goat 'part process'
acting -false- on rule 9
full testing rule 9 - targets: 'part' '1500 Ton Press'
attempting to satisfy goal 'part process'
acting -false- on rule 9
lull testing rule 9 - targets: 'part' '2000 Ton Roll
attempting to satisfy goal 'part process'
acting -false- on rule 9
attempting to satisfy goal 'part forming method
full testing rule 9 - targets: part' '12 Foot Roll
attempting to satisfy goal 'part process
acting -false- on rule 9
full testing rule 9 - targets: 'part' '250 Ton Press'
attempting to satisfy goal 'part process
acting -false- on rule 9
lull testing rule 9 - targets: 'Part '37.5 Ton Press'
attempting to satisfy goat 'part process
acting -false- on rule 9
full testing rule 9 - targets: 'part '60 Ton Cold Press'
attempting to satisfy goal 'part process' .
acting -false- on rule 9
full testing rule 9 - targets: part' '600 Ton Press'
attempting to satisfy goal 'part process'

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    acting -false- on rule 9
     full testing rule 9 - targets: 'part' 'Brake Press'
        attempting to satisfy goal 'part process'
    acting -false- on rule 9
     lull testing rule 9 - targets: 'part' 'Frame Bender
        attempting to satisfy goal 'part process'
    acting -false- on rule 9
     full testing rule 9 - targets: 'Part '1500 Ton Press'
        attempting to satisfy goal 'part process'
    acting -false- on rule 9
     full testing rule 9 - targets: 'part' '2000 To" Roll
        attempting to satisfy goal 'part process'
    acting -false- on rule 9
- - - forward inference - - -

     ********** C O N C L U S I O N S **********

the part process
   is cut process [certainty 1.00]
   is edge prep process [certainty 1.00]

the part edge prep method
   is N/C Plasma [certainty 1.00]
   is edge planer [certainty 1.00]

the part edge prep location
   is bay 3 [certainty 1.00]
   is bay 2 [certainty 1.00]

the part edge prep routing code
   is br2 [certainty 1.00]
   is pl1 [certainty I.00]

the part cut location
   is bay 3 [certainty 1.00]

the part cut routing cods
   is br2 [certainty 1.00]
   is br1 [certainty 1.00]

the part cut method
   is N/C Plasma [certainly 1.00]
   is N/C 2-Axis [certainty 1.00]

the part forming Iocation
    (no values)

the part forming routing code
    (no values)

the part forming method
    (no values)

     ********** C O N C L U S I O N S - - - - - - - - - -
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